Research Article

The impact of early spasticity on the intensive functional rehabilitation phase and community reintegration following traumatic spinal cord injury

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Context/Objectives: To determine the impact of spasticity presenting during the acute care hospitalization on the rehabilitation outcomes following a traumatic spinal cord injury (TSCI).
Design: Retrospective cohort study.
Setting: A single Level 1 trauma center specialized in SCI care.
Participants: 150 individuals sustaining an acute TSCI.
Interventions: Not applicable.
Outcome Measures: The total inpatient functional rehabilitation length of stay. The occurrence of medical complications and the discharge destination from the inpatient functional rehabilitation facility were also considered.
Results: 63.3% of the cohort presented signs and/or symptoms of spasticity during acute care. Individuals with early spasticity developed medical complications during acute care and during intensive functional rehabilitation in a higher proportion. They were also hospitalized significantly longer and were less likely to return home after rehabilitation than individuals without early spasticity. Early spasticity was an independent factor associated with increased total inpatient rehabilitation length of stay.
Conclusion: The development of signs and symptoms of spasticity during acute care following a TSCI may impede functional rehabilitation outcomes. In view of its association with the occurrence of early spasticity, higher vigilance towards the prevention of medical complications is recommended. Early assessment of spasticity during acute care is recommended following TSCI.

Keywords: Spinal cord injury, Spasticity, Rehabilitation, Acute care, Outcome

Introduction

Spasticity is a complex neurological syndrome characterized by a velocity-dependant hypertonia following a central nervous system lesion.[1] Spasticity involves 40–80% of individuals suffering from traumatic spinal cord injury (TSCI) and adversely so in 28–48% of them.[2] Spasticity is not only restricted to muscular hypertonia, but is rather part of a complex spectrum of signs and symptoms including spasms and clonus.[3,4]

Spasticity occurs during recovery from spinal shock, which corresponds to the depression of the spinal reflexes below the level of injury.[4,5] Spasticity is defined by Lance as "a motor disorder characterised by a velocity-dependent increase in tonic stretch reflexes (muscle tone) with exaggerated tendon jerks, resulting from hyper excitability of the stretch reflex".[6] Spasticity is not only restricted to muscular hypertonia, but is rather part of a complex spectrum of signs and symptoms, defined as the upper motoneurone syndrome

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(comprising spasms, clonus and Babinski sign).[3] The onset of muscle hypertonia, spasms and clonus is presumably due to a neuronal hyper sensibility and axonal sprouting.[7] Spasticity may lead to pain, mobility disorders, limit functional status as well as quality of life.[8–10] Accordingly, spasticity was reported as a top concern for patients in the chronic phase following TSCI.[11,12] As spasticity generally develops after the first month following a SCI (thus during the intensive functional rehabilitation phase),[7] the impact of spasticity on various outcomes (complication, functional recovery) has been reported during the chronic phase following TSCI. However, some individuals will develop signs and/or symptoms of spasticity earlier in the rehabilitation process, during the acute care phase. However, the impact of the development of spasticity during this period on the subsequent rehabilitation phase remains unknown.

The acute care hospitalization is an important step, since its course may significantly influence the long-term functional outcome following TSCI.[13] As the presence of spasticity may alter motor behaviors, impede mobility, and was showed to limit functional recovery in the chronic phase following TSCI,[12,14,15] it is hypothesized that early development of spasticity may also impede the intensive functional rehabilitation phase. Awareness of the implications of early spasticity could help clinicians in preventing complications related to spasticity (contractures, pressure ulcers, infections),[8] planning the rehabilitation process and improve long-term outcome.

Accordingly, the objective of this study was to determine the impact of early spasticity (developing during the acute care hospitalization) on the rehabilitation outcomes following a TSCI. Outcomes measures were the occurrence of medical complications, the rehabilitation length of stay (LOS), as well as the discharge orientation for individuals with and without early spasticity. Multivariable linear regression analyses were used to analyze the relationship between the presence of early spasticity and the total inpatient functional rehabilitation LOS considering important confounding factors.

Methods

Subjects

A retrospective cohort study of prospectively collected data including 156 consecutive patients admitted to a single Level 1 SCI-specialized trauma center between April 2010 and April 2017 and subsequently transferred to an affiliated intensive functional rehabilitation center for a TSCI was conducted. Patients were included if they sustained an acute TSCI between levels C1 to L1, if they required surgical management at our institution, and were aged 16 and over. Patients were excluded if information regarding discharge destination after intensive functional rehabilitation was missing (6 subjects). A final cohort of 150 patients was thus analyzed. This study was approved by our institutional Ethics review committee.

Our cohort was subdivided into two groups based on the development of spasticity during the acute care hospitalization. Group 1 included 55 (36.7%) individuals with a TSCI ("no early spasticity group") who did not develop spasticity during the acute care hospitalization, while Group 2 ("early spasticity group") included 95 individuals (63.3%) who developed spasticity during the acute care hospitalization. The development of spasticity was noted based on physical findings assessed by the attending treating team and symptoms reported by the patient. The diagnosis of spasticity required one of the following three criteria: 1) presence of increased velocity-dependant muscle tone at physical examination (Modified Ashworth scale score of >1); 2) spasm and/or clonus noted at physical examination, and 3) spasms and/or clonus reported by the patient.

Data collection

Socio-demographic, clinical and trauma-related data was retrieved from a local prospective database. Socio-demographic data included age and body mass index. The burden of comorbidities was assessed using the Charlson Comorbidity Index (CCI), which weighs 19 comorbidities based on the adjusted relative risk of one-year mortality.[16] The severity of the TSCI was assessed upon arrival to the acute care center and was reported using the American Spinal Injury Association (ASIA) impairment scale (AIS) grade (A to D), according to the International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI).[17] The neurological level of injury was categorized as high tetraplegia (C1-C4), low tetraplegia (C5-C8) or paraplegia (T1-L1). Trauma severity and the burden of associated traumatic injuries were assessed using the Injury Severity Score – ISS.[18] The presence and severity of concomitant traumatic brain injury was also collected.

The following complications that arose at anytime during the acute care hospitalization was noted: 1) overall respiratory complications (e.g. pneumonia, acute respiratory distress syndrome; pulmonary embolism; bronchitis; atelectasis; pulmonary edema; pneumothorax; etc.), 2) urinary tract infections (UTI) and 3) pressure ulcers (PU). The occurrence of respiratory complications was diagnosed using clinical features and confirmed by a radiologist using chest X-rays.[19] UTI were diagnosed using criteria from the 2006 Consortium for Spinal Cord Medicine Guidelines for healthcare providers.[20] Finally, the presence of PU was

diagnosed based on the clinical guidelines defined by the National Pressure Ulcer Advisory Panel (NPUAP).[21] A complication rate was calculated, referring to the proportion of patients who developed one of the above-mentioned complications during their stay at the acute care center, and was expressed as a percentage. The presence of PU was also assessed individually since the presence of spasticity in the chronic phase has been associated with increased prevalence of PU in a previous study.[8] The surgical delay was defined as the time (in hours) between the trauma and the spinal surgery (time of skin incision). The length of stay (LOS) was defined as the number of days from admission to discharge either from acute care (acute care LOS), or intensive functional rehabilitation center (intensive functional rehabilitation LOS). The total inpatient rehabilitation LOS refers to the number of days of hospitalization in IFR and transitional rehabilitation, when applicable.

Outcome variables

The total inpatient rehabilitation LOS consisted in our main outcome variable. The discharge destination after intensive functional rehabilitation was categorized into: 1) discharge home; 2) transitional inpatient rehabilitation facility; 3) long-term nursing home and others (readmission to acute care hospital, or death). More precisely, in the province of Quebec, when an extended period of intensive functional rehabilitation is required and "specialized" training is completed (sphincter management, SCI education, etc.), individuals are sent to an affiliated transitional rehabilitation facility. This transitional rehabilitation facility can provide additional mobility and functional training, while being less expensive than the specialized intensive functional rehabilitation facility.[22] This information was collected retrospectively using a review of the intensive functional rehabilitation clinical charts.

Data on medical complications (ITU, PU and pneumonia) developing during the intensive functional rehabilitation hospitalization was also collected using the same diagnosis criteria previously mentioned. The percentage of patients who developed multiple complications (more than one) during their intensive functional rehabilitation stay was also calculated.

Statistical analyses

In order to compare the two groups (early vs. no early spasticity), we first used non-parametrical analyses (Mann-Whitney tests for continuous variables and chi-square tests for categorical variables), considering that Kolmogorov-Smirnov tests revealed a non-normal distribution. We used the IBM SPSS Statistics Version 24 software package for all statistical analyses, using a level of significance of 0.05.

A General Linear Model (GLM) based on multivariable linear regression analyses was performed, using main effects and a backward elimination method to analyze the relationship between the presence of "early spasticity" (main independent variable) and the total inpatient rehabilitation LOS (dependent variable), accounting for clinical confounding factors available during acute care. Nine variables were entered in the multivariate model as covariables: 1) AIS grade; 2) neurological level of injury; 3) presence and severity of concomitant traumatic brain injury; 4) age (as continuous); 5) injury severity score (ISS) (as continuous); 6) comorbidities (CCI); 7) BMI (as continuous); 8) presence of complications during acute care; 9) surgical delay (as continuous). A total of 10 independent variables were thus included in the model, which is the maximum number of variables allowed to be input in a multivariable regression model for a cohort of 100 subjects, according to Green *et al.*[23] The strength of association was expressed using beta coefficients (ß coefficients), their 95% confidence interval (95%CI) and P values. The R-square value refers to the percentage of variance of the outcome variable explained by the independent variables included in the final GLM.

Finally, as secondary objective, a multinomial logistic regression analyses was performed in order to determine the impact of the occurrence of early spasticity on the discharge destination after intensive functional rehabilitation. The outcome (dependent) variable at this step was categorized into three categories: 1) discharge home, 2) discharge to transitional inpatient rehabilitation, and 3) discharge to long-term nursing care or others. Once more, the main independent variable was the development of early spasticity. Seven other variables were input in the multivariate model as covariables: 1) AIS grade; 2) neurological level of injury; 3) presence and severity of concomitant traumatic brain injury; 4) age (as continuous); 5) injury severity score (ISS) (as continuous); 6) comorbidities (CCI); 7) BMI (as continuous). Main effects statistic models were used. Discharge to a transitional inpatient rehabilitation center was defined as the reference category for the dependent variable in model A, while discharge home was defined as the reference category for model B. The strength of association with the discharge orientation was expressed in terms of odd ratios with 95% confidence interval (95%CI) and P values. Non-significant independent variables at the likelihood ratio test were excluded from the final model. The goodness-of-fit of the final model was expressed by the Nagelkerke R^2 value.

Results

Patient characteristics

A total of 150 patients with a mean age of 51.3 ± 18.2 years old were analyzed. Baseline characteristics of the final cohort, Groups 1 and 2 are shown in Table 1. A total of 95 (63.3%) patients developed spasticity during the acute care hospitalization (Group 2), while 55 (36.7%) did not (Group 1). A total of 56.8% individuals with a complete TSCI (AIS grade A) developed spasticity during acute care, as compared to 66.7%, 77,1% and 59.6% of patients with an AIS grade B, C and D, respectively (P = 0.26). Similarly, 59.3% of individuals with a C1-C4 cervical TSCI developed spasticity during the acute care, while 65.6% and 66.7% of individuals with lower cervical TSCI or paraplegia did (P = 0.70).

There were no significant difference between the two groups in terms of age, BMI, comorbidities, associated traumatic injuries (ISS), surgical delay and characteristics of the TSCI (NLI and AIS grade) (Table 1). However, individuals with early spasticity developed a higher proportion of medical complications during the acute care stay in comparison with individuals with no early spasticity (Table 1). Namely, the incidence of PU was significantly higher in the early spasticity group (Table 1). Finally, the acute care LOS reached almost 30 days in the early spasticity group, while it was closer to 20 days in the no early spasticity group (Table 1).

Comparison of the intensive functional rehabilitation outcomes is shown in Table 2. Individuals with early spasticity showed a tendency toward developing more medical complications during the intensive functional rehabilitation phase, however not reaching a significant difference (Table 2). Individuals in Group 2 were also hospitalized 20 days longer in intensive functional rehabilitation than individuals in Group 1 (Table 2). Almost 80% of subjects with no early spasticity were discharged home after intensive functional rehabilitation, as compared to only 58.9% in the early spasticity group (P = 0.05) (Table 2). Moreover, individuals with early spasticity were more likely to require an extended period of rehabilitation in a transitional inpatient rehabilitation facility than their counterparts. We conducted chi-square post-hoc tests based on adjusted standardized residuals in order to determine which specific discharge orientation after intensive functional rehabilitation was significantly different between the two groups. Adjusted standardized residuals allow standardizing in a normal distribution in order to compare values.[24] Post-hoc tests revealed that discharge home and referral to a transitional inpatient rehabilitation facility were significantly different between the two groups, with the latter contributing the most to the difference observed (adjusted standardized residual of 2.6). Ultimately, the final destination was significantly different between the two groups (Table 2). According to the post-hoc tests results, individuals with early spasticity were ultimately discharged to a private residence in a lower proportion as compared to the no early spasticity group (adjusted standardized residuals of 2.4). These individuals were also sent in a long-term nursing home in a higher proportion (adjusted standardized residuals of 2.0) (Table 2).

Results from the final GLM are shown in Table 3. Early spasticity was revealed as a significant factor associated with an increased total inpatient rehabilitation LOS (Table 3). The AIS-grade and the presence of acute medical complications were also significantly associated with an increased total inpatient rehabilitation LOS following TSCI.

Finally, results from the multinomial logistic regression models are shown in Table 4. From the eight independent variables included in the analyses, five were excluded (ISS, BMI, CCI, NLI and presence of concomitant traumatic brain injury), based on the likelihood ratio tests results (P > 0.05). Three independent variables (age, early spasticity and AIS grade) were thus included in the final model. Model A shows the impact of each independent variable on the likelihood of being discharged home and to a nursing home, as compared to being discharged in a transitional inpatient rehabilitation facility. Model B shows the impact for each independent variable on the likelihood of being discharged to a transitional inpatient rehabilitation facility and to a nursing home, as compared to being discharged home.

The absence of early spasticity increased five times the odds (OR = 4.96, p = 0.002) of being discharged home as compared to being discharged to a transitional inpatient rehabilitation facility (Table 4 A). The absence of early spasticity decreased the odds (OR = 0.2 p = 0.002) of being discharged to a transitional inpatient rehabilitation facility after intensive functional rehabilitation as compared to discharge home (Table 4 B). The goodness-of-fit for both models was fair, explaining 27.3% of the variance (Nagelkerke R^2 = 0.273).

Discussion

Spasticity is an important clinical issue for individuals with TSCI, associated to pain, interfering with mobility and quality of life.[8,25] This study is the first, to our

Table 1 Clinical characteristics for individuals with and without development of spasticity during the acute care hospitalization following a traumatic spinal cord injury (n = 150).

Characteristics			No early spasticity group (N = 55)	Early spasticity group (N = 95)	Total cohort (N = 150)	P value
Socio-demographic	Age	Mean (SD)	51.0 (20.2)	53.2 (16.9)	51.3 (18.2)	0.38
		Median (IQR)	53.0 (33.5–66.0)	55.0 (43.0–65.0)	53.5 (40.0–65.0)	
	BMI	Mean (SD)	24.0 (6.6)	23.2 (7.7)	23.7 (7.5)	0.65
		Median (IQR)	24.7 (20.5–27.7)	24.1 (20.4–28.1)	24.2 (20.4–27.7)	
	CCI	% 0	83.0	82.1	82.4	0.62
		% 1	11.3	10.5	10.8	
		% 2	1.9	5.3	4.1	
		% 3	1.9	1.1	1.4	
		% 4	0	0	0	
		% 5	0	1.1	0.7	
		% 6	1.9	0	0.7	
Initial trauma	AIS grade	% A	36.5	27.2	30.6	0.26
		% B	11.5	13.0	12.5	
		% C	15.4	29.3	24.3	
		% D	36.5	30.4	32.6	
	NLI	% C1-C4	47.1	39.8	42.4	0.70
		% C5-C8	21.6	23.9	23.0	
		% T1-L1	31.4	36.4	34.5	
	ISS	Mean (SD)	22.1 (6.4)	23.2 (10.4)	23.0 (8.8)	0.97
		Median (IQR)	20.0 (17.0–26.0)	20.0 (17.0–26.0)	20.0 (17.0–26.0)	
	Concomitant TBI	% none	54.5	50.0	51.7	0.80
		% mild	43.6	45.7	45.0	
		% moderate	1.8	3.2	2.7	
		% severe	0	1.1	0.7	
Acute care clinical evolution	Presence of medical complications (%)		24.5	57.4	45.6	$<10^{-3}$*
	Presence of pressure ulcers (%)		9.4	31.9	23.8	10^{-3}*
	LOS (days)	Mean (SD)	21.6 (10.4)	29.3 (14.7)	26.7 (14.1)	10^{-3}*
		Median (IQR)	18.0 (15.0–27.5)	27.0 (17.0–36.0)	23.0 (17.0–32.8)	
	Surgical delay (hours)	Mean (SD)	301.9 (1167.0)	78.6 (128.8)	158.1(704.0)	0.52
		Median (IQR)	23.2 (15.0–77.1)	26.2 (17.7–68.6)	24.6 (16.5–69.8)	

BMI, Body Mass Index; CCI, Charlson Comorbidity Index; AIS, American Spinal Injury Association Impairment Scale; NLI, Neurological level of injury; TBI, traumatic brain injury; ISS, Injury severity score; LOS, length of stay.
*P is significant if <0.05.

knowledge, to demonstrate the negative impact of early spasticity on the intensive functional rehabilitation outcomes and community reintegration.

A majority of our cohort (63.3%) developed signs and/or symptoms of spasticity (as defined in this study as the presence of the following: 1) velocity-dependant muscle hypertonia, 2) spasms reported by the patient or noted at physical examination, 3) clonus reported by the patient or noted at physical examination, during the acute care hospitalization. The incidence of spasticity observed in this study is in the lower range previously reported in the SCI population (65–78%).[2,8] This result was expected since previous studies have investigated the incidence of spasticity in the subacute or chronic phases following TSCI. This study suggests that a great majority of individuals who will develop spasticity will present signs and/or symptoms within the first month following the injury. This finding may help in defining the natural history of spasticity, as the proportion of individuals who develop spasticity prior to admission to intensive functional rehabilitation has never been reported in the SCI literature, to our knowledge. It is important to note that our cohort was similar to the Canadian SCI population in term of baseline characteristics.[26]

Results also showed that individuals with early spasticity were hospitalized significantly longer (both acute care and intensive functional rehabilitation) as compared to their counterparts, despite similar baseline and injury characteristics. The occurrence of spasticity

Table 2 Comparison of the outcomes for individuals with or without early spasticity following a traumatic spinal cord injury (n = 150).

Characteristics			No early spasticity group (N = 55)	Early spasticity group (N = 95)	P value
IFR clinical evolution	Presence of medical complications (%)		70.9	83.2	0.10
	Presence of pressure ulcers (%)		23.6	28.4	0.57
	Presence of multiple complications (%)		21.8	33.7	0.14
	IFR LOS (days)	Mean (SD)	62.9 (41.5)	77.7 (36.6)	**0.01***
		Median (IQR)	49.5 (35.5–81.0)	85.0 (44.0–105.3)	
	Total inpatient rehabilitation LOS (days)	Mean (SD)	73.3 (65.3)	123.1 (103.3)	**0.002***
		Median (IQR)	49.5 (35.5–81.0)	88.0 (44.0–165.0)	
IFR discharge orientation	% Private residence		78.2**	58.9**	**0.05***
	% Transitional rehabilitation		12.7**	31.6**	
	% Nursing home/long term care		1.8	4.2	
	% Other		7.3	5.3	
Final orientation	% Private residence		98.2**	86.3**	0.053
	% Assisted living residence		0	3.2	
	% Nursing home/long term care		1.8**	10.5**	

IFR, Intensive functional rehabilitation.
*P is significant if ≤0.05; **Results of post-hoc tests (μ is significant if ≤0.05).

early in the continuum of care may thus interfere with the rehabilitation process significantly enough to influence the discharge destination after intensive functional rehabilitation. Indeed, individuals with early spasticity were more likely to require extended inpatient rehabilitation in a transitional facility than individuals who have not developed spasticity in acute care. Moreover, spasticity increased the odds five-fold of transferring to an inpatient transitional rehabilitation center after IFR as opposed to discharging home, after considering clinical confounding factors.

Several hypotheses may be considered. First, motor behaviors related to spasticity (muscle hypertonia, antagonist muscle co-activation and spasms activity) were showed in the SCI and stroke literature to impose significant challenges for rehabilitation.[27–30] The occurrence of these motor behaviors early in the continuum of care may generate higher challenges in the functional training, which may impede the whole subsequent rehabilitation process. This highlights the impact of spasticity relatively to the continuum of care, and the importance of a proper acute rehabilitation process following a TSCI.

Table 3 Clinical factors associated with the total inpatient rehabilitation length of stay: results of the final general linear model (n = 150).

Predictive factors	ß (95%CI)	P value
Early spasticity		
Absence (Group 1)	−39.7 (−69.7;−9.7)	**0.01***
Presence (Group 2)	Ø	
Initial AIS grade		
AIS-A	100.0 (65.0;135.1)	**$<10^{-3}$***
AIS-B	75.2 (30.3;120.1)	**0.001***
AIS-C	51.7 (15.0;88.4)	**0.006***
AIS-D	Ø	
Complications during acute care		
Absence	−34.9 (−64.5;−5.2)	**0.02***
Presence	Ø	
R-square = 31.9%		

AIS, American Spinal Injury Association Impairment Scale.
Ø: Reference category.
*P is significant if <0.05.

Then, spasticity may also indirectly impact the rehabilitation process arising from its association with medical complications. Indeed, individuals with early spasticity sustained a higher proportion of medical complications during acute care compared to patients without early spasticity. The association between spasticity and medical complication has already been demonstrated in previous work.[8,29] However, it is difficult to determine in which direction these two factors are related, as the timing of occurrence during acute care was not considered in this study. In one hand, spasticity may promote PU and contractures, which can ultimately lead to immobility and other complications.[29] On the other, the nociceptive input related to medical complications may increase signs and symptoms of spasticity.[1] Both processes may have contributed to results of this study. The association between spasticity and medical complications is also likely to have participated to the longer LOS observed in this study.[31] It is thus recommended that the acute rehabilitation team maintain a high vigilance towards the prevention/treatment of medical complications (particularly in terms of PU) for patients with early spasticity.

Table 4 Factors associated with orientation discharge *after intensive functional rehabilitation* (IFR): results of the multinomial logistic regression model (n = 150).

Model A) Transitional inpatient rehabilitation facility as reference category

Discharge orientation	Predictive factors	Odd ratio (95%CI)	P value
Home	*Early spasticity*		
	Absence (Group 1)	4.96 (1.80;13.62)	**0.002***
	Presence (Group 2)	Ø	
	Initial AIS grade		
	AIS-A/B	0.13 (0.05;0.35)	**$<10^{-3}$***
	AIS-C/D	Ø	
	Age	1.00 (0.97;1.03)	0.97
Nursing home/long term care and other	Age	1.05 (1.01;1.10)	**0.03***
	Early spasticity		
	Absence (Group 1)	3.13 (0.75;13.09)	0.12
	Presence (Group 2)	Ø	
	Initial AIS grade		
	AIS-A/B	0.67 (0.16;2.80)	0.59
	AIS-C/D	Ø	

AIS, American Spinal Injury Association Impairment Scale.
Ø: Reference category.
*P is significant if <0.05.

Model B) Discharge home as reference category

Discharge orientation**	Predictive factors	Odd ratio (95%CI)	P value
Transitional rehabilitation facility	*Early spasticity*		
	Absence (Group 1)	0.20 (0.07;0.55)	**0.002***
	Presence (Group 2)	Ø	
	Initial AIS grade		
	AIS-A/B	7.44 (2.86;19.34)	**$<10^{-3}$***
	AIS-C/D	Ø	
	Age	1.00	0.97
Nursing home /long term care and others	*Initial AIS grade*		
	AIS-A/B	4.99 (1.32;18.95)	**0.02***
	AIS-C/D	Ø	
	Age	1.05 (1.01;1.09)	**0.02***
	Early spasticity		
	Absence (Group 1)	0.63 (0.189;2.15)	0.46
	Presence (Group 2)	Ø	

AIS, American Spinal Injury Association Impairment Scale.
Ø: Reference category.
*P is significant if <0.05.

Patho-physiological mechanisms underlying spasticity may provide possible solutions in terms of early spasticity management. A previous study by Li *et al.* in 2017[30] suggested that spasticity and motor recovery have different underlying mechanisms, but may be both related to neural plasticity. Accordingly, it was suggested that facilitation and modulation of neural plasticity through rehabilitation strategies, such as interventions with repetitive goal-oriented intensive therapy and pharmaceutical agents may be the key to promote recovery.[30] It was also suggested that early assessment and interventions for spasticity may create a transient plastic state of the neuromotor system allowing higher motor re-learning and neuro-functional recovery.[30] Aggressive management of early spasticity with non-pharmaceutical interventions (positioning, range of motion, stretching, weight-bearing, muscle strengthening, electrical stimulation, cold/heat application, splinting/orthosis is thus recommended.[32] Some of these interventions aim to decrease the occurrence of complications related to the presence of spasticity, such as contractures.

Despite the negative effects of early spasticity presented in this study, it is also important to highlight that spasticity may also be beneficial on different aspects following TSCI. In fact, previous studies showed evidence that spasticity may defend skeletal muscle size and composition, as well as bone health and circulation.[33] Spasticity may also serve as a warning mechanism to identify pain or problems in areas of no sensation.[8] Symptoms of spasticity may, in some individuals, increase stability in sitting and standing, facilitate the performance of some ADL and transfers, as well as increase strength of spastic muscles (thereby helping prevent osteopenia).[8] However, the

intensity to which spasticity comes to interfere for functional activities remains personal and thus difficult to quantify. Results of this study may thus possibly suggest that early development of spasticity following TSCI may be associated with spasticity interfering with functional recovery and activities. This may reinforces the importance of early assessment of spasticity during acute care following TSCI.

Limitations

The main limitations of this study relate to its retrospective nature and the low number of patients. This study also took place in a single hospital center limiting its external validity**.** The authors also acknowledge that information pertaining to the severity, timing and clinical signs/symptoms of spasticity could have helped in better understanding its relationship with the intensive functional rehabilitation outcomes. A prospective cohort study is thus recommended. Finally, this study cannot draw any conclusions on the impact of the occurrence of early spasticity *in terms of time* after the injury, since the acute care LOS was significantly different between the two groups. However, this study aimed to investigate the impact of early spasticity *with respect to the rehabilitation phases* as part of the continuum of care following TSCI. Using timeline of spasticity in terms of rehabilitation phases may help clinicians to ultimately better define the objectives of the acute rehabilitation, which still remain unclear to date.

Conclusion

A total of 63.3% of individuals sustaining an acute TSCI developed signs and/or symptoms of spasticity. The occurrence of spasticity during the acute care hospitalization following TSCI may delay the intensive rehabilitation process and increased the odds of being transferred to an inpatient transitional rehabilitation center as opposed to be discharged home after intensive functional rehabilitation. Individuals with early spasticity may experience additional challenges from motor control deficits and experience a higher number of medical complications, which may impede the rehabilitation process. It is possible that early spasticity may also be associated with spasticity, interfering with functional activities. Thus, early assessment of spasticity during acute care is thus recommended following TSCI. Higher vigilance towards the prevention of medical complications in these patients is also recommended as these two factors may be interrelated.

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Declaration of interest None.

Conflicts of interest Authors have no conflict of interests to declare.

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